**Division of Oil, Gas, and Geothermal Resources**

# TULARE AQUIFER EXEMPTION DOCUMENT
# ELK HILLS OIL FIELD, KERN COUNTY
## Executive Summary

As required in the Safe Drinking Water Act and based upon the criteria in 40 Code of Federal Regulations (CFR) 146.04, the State of California is requesting a non-substantial aquifer exemption to expand the already utilized injection area in the Elk Hills oil field, located in Kern County. As the State Oil and Gas Supervisor for the Division of Oil, Gas, and Geothermal Resources (DOGGR), and as the State's Class II Underground Injection Control Program Administrator under the Memorandum of Agreement (MOA) providing the State of California Primacy for Class II injection wells, the State is providing this application and supporting information to the United States Environmental Protection Agency (US EPA) in conformance with the MOA dated September 29, 1982.

DOGGR, so as to encourage the wise development of oil and gas resources to best meet oil and gas needs in this state, approves injection of produced water as necessary, which is a part of the development of these resources. To allow for continued oilfield development of the Elk Hills oil field, DOGGR is providing documentation for the aquifer exemption of the Tulare Formation. The project area, referred to in this document as the Elk Hills Tulare aquifer exemption area, is shown in Exhibit 1. **(Please note that Exhibits 1 – 3 are copied into this Executive Summary, however, all other Exhibits referenced in this Executive Summary may be located in the attached Tulare Aquifer Exemption Document, prepared by San Joaquin Energy Consultants, Inc. for Occidental of Elk Hills, Inc.).** The Tulare aquifer exemption is for the purpose of continuing Class II UIC operations in the Elk Hills oil field. The Tulare aquifer exemption interval includes all of the saturated upper Tulare zone and both the unsaturated and saturated lower Tulare zone below the Amnicola claystone confining zone.

The already utilized Tulare injection area originally consisted of 72.4 square miles, or about 99% of the Elk Hills oil field. After meetings and discussions between Oxy Elk Hills Inc. (OEHI), San Joaquin Energy Consultants (SJEC), and representatives from the West Kern Water District (WKWD), the Kern County Water Agency (KCWA), and the Kern Water Bank Authority (KWBA), the northeastern flank area of the Elk Hills oil field was excluded from the already utilized Tulare injection area. The proposed Tulare aquifer exemption area currently consists of about 59.0 square miles, or about 80% of the Elk Hills oil field.

Based on 40 CFR §146.4, the Tulare aquifer exemption is justified on the following grounds:
1) It does not currently serve as a source of drinking water, and
2) It cannot now and will not in the future serve as a source of drinking water because:
   a) It is situated at a depth or location which makes recovery of water for drinking

water purposes economically or technologically impractical;
b) It is so contaminated that it would be economically or technologically impractical to render that water fit for human consumption; and
c) The total dissolved solids (TDS) content of the groundwater is more than 3,000 and less than 10,000 milligrams/liter (mg/l) and it is not reasonably expected to supply a public water system.

The following reasons support an aquifer exemption of the Tulare Formation within the already utilized Tulare injection area, which is defined as the 59.0-square mile Elk Hills Tulare aquifer exemption area plus a buffer zone with a fixed distance of 0.25 mile.

1. The WKWD, the local water provider in the area, has declared that the Tulare Formation within the proposed Elk Hills aquifer exemption area does not currently serve as a source of drinking water and will not reasonably be expected to supply a public water system (Exhibit 3).

2. The Tulare Formation in the Elk Hills oil field was referred to and treated as an exempt aquifer by the EPA when it authorized Class I non-hazardous injection in two Tulare disposal wells for Elk Hills Power, LLC, under UIC Permit #CA200002. In addressing public comments received during the review process, the US EPA wrote that it "… had made the determination that the Tulare Formation within the Area of Review is an exempt aquifer." The area of review for the Elk Hills Power UIC permit was in section 18, T31S/R24E, which has Tulare groundwater that is comparable in its poor quality to other areas of the Elk Hills oil field. The original UIC permit, dated February 21, 2001, was later modified to authorize two additional Tulare injection wells on June 3, 2004. Nearly 35 million barrels (bbls) of industrial, nonhazardous fluids produced during the operation of the Elk Hills Power Plant were injected into the Tulare Formation in the 18G area.

3. The Tulare Formation has been used since July 1981 for injection of produced water. Although this was after the DOGGR's submittal of its 1981 Primacy Application, it was well before the EPA granted the DOGGR primacy on March 14, 1983. In this 14-month interim, the Tulare Formation in the Elk Hills oil field was not part of any amendment to the Primacy Application. As a result, it was omitted as an exempt aquifer based on being a non-hydrocarbon producing zone used for wastewater disposal.

4. A large portion of the Tulare Formation within the Elk Hills oil field has been regularly described and treated by the DOGGR as an exempt aquifer for Class II UIC injection. Two Class II injection projects and several project expansions were approved by the DOGGR. More than 130 Tulare wastewater disposal wells have been permitted since July 1981, through which more than one billion bbls of Class II formation water have been disposed. Past and current Class II injection operations in the project area have contributed to groundwater degradation in the Tulare aquifer exemption area. Naturally saline produced water disposed in the relevant portions of the Tulare Formation has TDS concentrations in excess of 28,000 mg/l as well as high concentrations of iron, chloride, and boron.

5. The proposed Tulare aquifer exemption area is adjacent to oil fields in which all or

part of this formation has been exempted based on being used for disposal of naturally saline Class II wastewater and/or commercial oil and gas production. The Tulare Formation is stratigraphically continuous throughout the proposed aquifer exemption area and with the adjacent fields in which it already is an exempt aquifer.

6. The Tulare Formation in the Elk Hills oil field locally contains groundwater that has TDS concentrations greater than 10,000 mg/l in intervals near its base and does not meet the definition of a protected USDW in those intervals.

7. Tulare groundwater in the Elk Hills oil field contains a lead concentration that exceeds the primary maximum contaminant level (MCL) for drinking water and concentrations of TDS, chloride, and sulfate that exceed secondary MCLs. Boron, strontium, and sodium concentrations in Tulare groundwater are significantly in excess of regulatory thresholds for human health, agricultural uses, and/or livestock watering. Iron concentrations are variable but also can exceed secondary MCLs and regulatory thresholds for human health, respectively.

8. The designated beneficial uses of groundwater within the area of review are municipal and domestic supply (MUN), agricultural supply (AGR), and industrial service supply (IND). However, the poor quality of Tulare groundwater renders it unusable for domestic or agricultural usage because: its lead concentration exceeds the California Title 22 primary MCL for drinking water; TDS, chloride, and sulfate concentrations exceed secondary drinking water MCLs; and boron, strontium, and sodium concentrations exceed regulatory thresholds for human health, agricultural uses, and/or livestock watering. Iron is variable but also can exceed the secondary MCLs for drinking water and regulatory thresholds for human health, respectively. The occurrence of petroleum in local areas of the Elk Hills oil field also contributes to Tulare groundwater degradation and adversely affects its designated beneficial uses.

9. The proposed Tulare aquifer exemption area is located in a remote and sparsely populated area of Kern County. Land in the proposed Tulare aquifer exemption area is zoned as agricultural but only a small portion of section 13G in the Elk Hills oil field is irrigated as farmland. The primary use of land within the area of review is related to oilfield operations.

10. Based on water well database searches, well records review, and site reconnaissance, there are no known water wells located within the area of review.

11. Domestic, agricultural, and industrial water in the proposed Tulare aquifer exemption area is supplied primarily by water from the State Water Project (SWP) via the California Aqueduct and two WKWD well fields. According to its 1997 *Groundwater Management Plan*, the WKWD believed that: 1) its water supplies were adequate to meet peak daily demands and future needs; and 2) despite potential shortages in SWP deliveries, it did not need to pursue additional sources of water.

12. An evaluation of the economic feasibility of treating Tulare groundwater in the McKittrick area for use as drinking water concluded that treating this groundwater would cost about 12 to 70 times the current potable water treatment cost per household. The US EPA criteria for designating Tulare groundwater as Class III based on economic

infeasibility, were met because the total annual system cost per area household to treat Tulare groundwater: a) exceeded 0.4% of the median annual household income; b) was more than 100% of the current water rate; and c) was greater than the ninetieth percentile economic untreatability threshold of $379.14 per household. Concentrations of TDS, chloride, sulfate, boron, and sodium in McKittrick area groundwater are comparable to Tulare groundwater in the Elk Hills field. However, Elk Hills Tulare groundwater also has higher concentrations of lead and hydrocarbons, the removal of which would increase treatment costs and, consequently, increase the economic infeasibility to treat it for use as drinking water.

13. The Tulare groundwater in the Elk Hills oil field has low resource value or beneficial uses except for its use in Class I non-hazardous and Class II UIC injection operations.

## PROPOSED EXEMPTION AREA DESCRIPTION

The proposed Tulare aquifer exemption area is located on the western side of the southern San Joaquin Valley (Exhibit 1). The already utilized Elk Hills Tulare injection area originally was 72.4 square miles and included about 99% of the Elk Hills oil field lying within the DOGGR's administrative field limits. After meetings and discussions between OEHI, SJEC, and representatives of the WKWD, the KCWA, and the KWBA, the northeastern flank of the Elk Hills oil field was excluded from the already utilized Tulare injection area, reducing the total area to about 80% of the field. The proposed Tulare aquifer exemption area currently consists of about 59.0 square miles, or 37,780.2 acres, and includes nearly all of the Elk Hills oil field lying within the DOGGR's administrative limits, with the exception of the following areas (Exhibit 2):

Township 30 South, Range 24 East (= S)
All of section 17
All of section 18
All of section 19
All of section 20
All of section 21
All of section 22
South 1/2 of the Southwest 1/4 of Section 25
All of section 26
All of section 27
All of section 28
All of section 29
All of section 30
All of section 34
All of section 35
All of section 36

Township 30 South, Range 25 East (= T)
The following portions of Section 31:
South 1/2 of Southwest 1/4 of Northwest 1/4

Southwest 1/4

The area of review for this document consists of the 59.0-square mile of already utilized Tulare injection area plus a buffer zone with a fixed distance of 0.25 mile, as shown on Exhibit 1 and Exhibit 2.

The proposed Tulare aquifer exemption interval consists of all of the saturated upper Tulare zone and both the unsaturated and saturated lower Tulare zone below the Amnicola claystone confining zone.

The following is a description of the proposed Tulare aquifer exemption area:

Township 30 South, Range 22 East (= Z)
The following portions of Section 10:
North 1/2
North 1/2 of Southeast 1/4
South 1/2 of Section 11:
All of Section 13
The following portions of Section 14:
North 1/2
Southeast 1/4
The following portions of Section 23:
Northeast 1/4
North 1/2 of Southeast 1/4
Southeast 1/4 of Southeast 1/4
All of Section 24
Northeast 1/4 of Section 25
Township 30 South, Range 23 East (= R)
All of Section 7
All of Section 8
All of Section 13
All of Section 14
All of Section 15
All of Section 16
All of Section 17
All of Section 18
All of Section 19
All of Section 20
All of Section 21
All of Section 22
All of Section 23
All of Section 24
All of Section 25
All of Section 26
All of Section 27
All of Section 28
All of Section 29

All of Section 30
All of Section 32
All of Section 33
All of Section 34
All of Section 35
All of Section 36
Township 30 South, Range 24 East (= S)
All of Section 31
All of Section 32
All of Section 33
Township 31 South, Range 23 East (= B)
All of Section 1
All of Section 2
All of Section 3
All of Section 4
All of Section 10
All of Section 11
All of Section 12
All of Section 13
Township 31 South, Range 24 East (= G)
All of Section 1
All of Section 2
All of Section 3
All of Section 4
All of Section 5
All of Section 6
All of Section 7
All of Section 8
All of Section 9
All of Section 10
All of Section 11
All of Section 12
All of Section 13
All of Section 14
All of Section 15
All of Section 16
All of Section 17
All of Section 18
Township 31 South, Range 25 East (= M)
The following portions of Section 6:
Northwest 1/4
Northwest 1/4 of Southwest 1/4

Please note: The Division can provide the appropriate GIS files that will delineate the area in question upon request.

## DECLARATION FROM LOCAL WATER AGENCY

The WKWD has the authority to provide water to municipal and industrial users within the area of review. It has provided the DOGGR with a letter stating that the Tulare Formation within the proposed Elk Hills aquifer exemption area does not currently serve as a source of drinking water and would not reasonably be expected to supply a public water system (Exhibit 3).

## AQUIFER CHARACTERIZATION

### Description of Aquifer

Topography shows that the Elk Hills oil field is deeply cut by canyons that trend either north or south from the crest of the hills (Exhibit 2). The crest of Elk Hills lies about 1,000 feet above the valley floor, and canyons commonly are 75 to 200 feet deep. All areas of topographic relief in the field have the Tulare Formation in outcrop (Exhibit 15).

The Tulare groundwater in the area of review lies within the Kern County Subbasin of the San Joaquin Valley Groundwater Basin (Exhibit 16; California Department of Water Resources, 2006). The Kern County Subbasin has interior drainage and no appreciable surface or subsurface outflow, except during extremely wet years (Kern County Water Agency, 2008). The Elk Hills oil field lies within Detailed Analysis Unit (DAU) Nos. 259 and 260 of the Kern County Subbasin (Exhibit 17; California Regional Water Quality Control Board, 2004). The designated beneficial uses for DAU No. 259 are MUN, AGR, and IND. The designated beneficial uses for DAU No. 260 consist only of MUN and IND.

The structure and stratigraphy of the Tulare Formation within the area of review is shown in the type logs (Exhibit 18), the structure contour map of the base of the Tulare Formation, the isochore map of the gross thickness of the Tulare Formation (Exhibit 20), and structural cross-sections (Exhibit 21).

The Tulare Formation is the primary groundwater-bearing zone in the Elk Hills oil field. It consists of fluviatile and lacustrine deposits of gravel, sand, silt, clay, and limestone. The Tulare Formation at Elk Hills contains three informal members: the upper and lower Tulare and, separating the two, the Amnicola claystone. The Tulare contains nonmarine sediments deposited in floodplain, fluvial channel, and lake environments. Fluvial channels are coarse- to very coarse-grained and fine upward to medium- and coarse-grained sand. Porosity and permeability are very good. Sand intervals are generally loose and unconsolidated. Floodplain sediments consist of clay and sandy siltstone. The Amnicola claystone consists of silty claystone and probably was deposited in a lacustrine setting. Floodplain deposits are more common in the lower Tulare, whereas fluvial channels comprise most of the upper Tulare.

Two prominent lacustrine clay or claystone units occur within the Tulare Formation and can act as effective confining zones. The Amnicola claystone, which separates the upper and lower Tulare, consists of a dark brown-gray, lacustrine claystone with thin, rare siltstones. The Tulare clay occurs within the upper part of the formation and is a thick unit of clay and interbedded clay-gravel. The portion of the Tulare Formation above the Amnicola claystone has the best porosity and permeability and is the most suitable zone in the Elk Hills oil field for produced water injection.

In the proposed aquifer exemption area, the Tulare Formation conformably overlies the shallow marine deposits of the San Joaquin Formation (Exhibit 18 through Exhibit 21). The San Joaquin Formation lying immediately beneath the Tulare is composed of shale and silt and contains characteristic marine fossils and shells. It produces natural gas and formation water with high TDS concentrations.

Across most of the Elk Hills oil field, the Tulare Formation crops out at the surface. Holocene-age alluvium is present only at the most down-dip flanks of the field to the north, south, and east. The contact between the top of the Tulare, where present, and the base of the alluvium was originally established by geologic mapping (Woodring et al., 1932) and later refined using aerial photographs.

The base of Tulare Formation was based on the definition used by the U. S. Geological Survey (USGS) in Maher et al. (1975). It was placed at the transition between the marine tidal marsh and channel deposits of the San Joaquin Formation and the fluvial and lacustrine sands of the Tulare. Correlations of the first Tulare sand are relatively consistent across Elk Hills. A higher well density based on recent well data allowed a more accurate view of correlations, and USGS tops were modified locally as improved correlations were identified.

The base of the Tulare Formation in the subsurface ranges from elevations of +500 feet in the axial crest of the anticline to -2,500 feet in the Buena Vista Valley area (Exhibit 19). Although only a single major anticline is present in the surface outcrops of Elk Hills, two culminations are apparent at the base of the Tulare Formation: the western 29R Anticline in sections 28R and 29R and the eastern 31S Anticline in sections 25R, 36R, 30S, and 31S. At the south edge of the map, the Buena Vista Syncline can be recognized in section 14G, and, further to the south, the edge of the Buena Vista Anticline is apparent.

The gross thickness of the Tulare Formation ranges from about 1,100 feet along the axial crest of Elk Hills to more than 2,500 feet on the north flank and 3,000 feet in the Buena Vista Valley (Exhibit 20). Flank thickness may include alluvium because it is difficult to differentiate it from the Tulare in these areas.

Five significant normal faults break only the base of the Tulare Formation in the eastern Elk Hills area. These are extensions of deeper faults that reach reservoirs in the San Joaquin and Etchegoin Formations. Faults have up to 300 feet of offset. The downthrown blocks are to the northwest.

From a hydrogeologic standpoint, the Tulare Formation can be divided into two zones: 1) the shallow unsaturated Tulare zone and 2) the deeper, saturated Tulare zone. The

Tulare aquifer exemption interval includes all of the saturated upper Tulare zone and both the unsaturated and saturated lower Tulare below the Amnicola claystone confining zone.

a. Unsaturated Tulare Zone

The upper intervals of the Tulare Formation consist of sand, conglomerates, and finer-grained sediments that are completely dry or at irreducible water saturation and are referred to in this document as the unsaturated Tulare zone. The extent of the unsaturated Tulare zone, which occurs in the area of the axial crest of Elk Hills, is shown as the yellow highlighted area in Exhibit 20. The unsaturated Tulare zone below the Amnicola claystone confining zone is part of the aquifer exemption interval.

The structure map of the base of the unsaturated Tulare zone was made by finding the lowest occurrence of the density-neutron crossover in the Tulare in each well (Exhibit 22). In some instances, and mostly in outlying areas, resistivity was used when the density and neutron curves were absent. In these cases, the base of the unsaturated Tulare zone was picked where resistivity drops from consistently higher values (>10 ohm-m) to lower values (<5 ohm-m) in clean sands.

The base of the unsaturated Tulare zone is not necessarily the same as the top of the saturated Tulare zone. Actual air-water contacts are rare in the data set because individual Tulare sand beds generally are too thin to recognize these contacts. The base of the unsaturated interval is more consistent in the upper Tulare because it is a more sand-rich section. Where the unsaturated base occurs in the lower Tulare, the horizon is more variable because of the low net sand that is characteristic of the interval.

Along the crest of Elk Hills, the base of the unsaturated zone is coincident with or close to the base of the Tulare Formation. In these areas, the unsaturated Tulare zone reflects the structure formed by the Elk Hills anticline. On the flanks of the Elk Hills anticline, the base of the unsaturated Tulare is relatively horizontal and can cross the dipping strata of the Tulare. Where the Tulare has a low net sand content, typically in the lower Tulare, the base of unsaturated interval is more variable. Although the Amnicola claystone is a well-documented confining zone in the Elk Hills area, the base of the unsaturated zone can be at a relatively similar level in the upper and lower Tulare. This may be because: 1) groundwater levels may be slightly different but masked by the variability of the mapping methods or the age of the well logs, and 2) the base of the unsaturated Tulare zone may be influenced more by the structural growth of the Elk Hills anticline and a weak groundwater system that has no appreciable recharge and low pressures, resulting in groundwater levels in both Tulare members reaching similar levels. Other cross-sections also show slightly different groundwater levels between the lower and upper Tulare, particularly in the south flank area (Exhibit 21-1: Exhibit 21-2), in the eastern and western Elk Hills area (Exhibit 21-3) and to a lesser extent on the north flank (Exhibit 21-2). The elevation of the base of the unsaturated Tulare zone ranges from about +80 feet in the northwestern area to +520 feet in the area of sections 28R and 29R (Exhibit 22).

The isochore map of the gross thickness of the unsaturated Tulare zone represents the difference between the ground surface elevation on the topographic map and the elevation of the base of the unsaturated Tulare zone grid (Exhibit 23). Contours are very crenulated because of the deep erosion of the ground surface. The yellow area shows that 100% of this interval is unsaturated, as indicated by the density-neutron crossover. At the crest of Elk Hills, there are up to 1,100 feet of unsaturated Tulare zone. The unsaturated interval thins to less than 100 feet off the northeastern and southeastern flanks of Elk Hills. Where present, some of this outlying interval may include alluvium because it is difficult to differentiate it from the uppermost Tulare Formation.

It is important to note that the isochore map of the gross thickness of the unsaturated Tulare zone is based on density-neutron log coverage. The surface to the top of the logged interval, typically 50 to 300 feet thick, is included in this map. Shallow boreholes drilled across several sections in Elk Hills confirm that the uppermost interval of the Tulare also is unsaturated. An example of some of the data used to determine if shallow perched groundwater is present in the Tulare zone is included for the Stantec 43-36R in Exhibit 24. Based on these boreholes, the deeply eroded Tulare surface, and the dip of the anticlinal limbs of the Elk Hills structure, it is unlikely that there would be any naturally-occurring, saturated sands in the shallowest Tulare Formation in Elk Hills.

b. Saturated Tulare Zone

The saturated Tulare zone can occur either above or below the Amnicola claystone in the Tulare Formation, both of which are part of the proposed Tulare aquifer exemption interval (Exhibit 21). The isochore of the gross thickness of the saturated Tulare represents the unedited difference between the base of the unsaturated Tulare zone and base of the Tulare grids (Exhibit 25). The yellow area on the isochore map shows where the entire interval of the Tulare is unsaturated. In this area, there may be as much as 40 feet of interval below the base of the unsaturated Tulare zone which is included in the unsaturated zone. This is because the base of the Tulare can contain no clean sand that would trigger the density-neutron crossover effect.

The gross thickness of the saturated Tulare zone ranges from 0 feet along the axial crest of Elk Hills to greater than 2,500 feet in the north flank area and 2,800 feet in the Buena Vista Valley on the south flank. In sections 25R and 26R, there is a small lens of saturated zone in the lower Tulare within the yellow-colored, unsaturated interval. This area is coincident with the saddle between the 31S and 29R Anticlines and may contain groundwater in sands at the base of the Tulare, with a maximum gross thickness of 200 feet.

Groundwater in the saturated Tulare zone can occur under unconfined or semi-confined conditions where confining strata are absent or below the Amnicola claystone in the axial crest area (Exhibit 21). Saturated Tulare sands also can occur under confined conditions, especially below the Amnicola claystone along the flanks of Elk Hills (Exhibit 21).

2. Depth of Aquifer

The saturated Tulare zone is not present over the axial crest area of the Elk Hills oil field. Where present, the depth to the base of the unsaturated Tulare zone ranges from about 380 feet in the 18G area to 1,050 feet in the 30R (Exhibit 22). The base of the unsaturated Tulare zone is not necessarily the same as the top of the saturated Tulare zone because individual Tulare sand beds generally are too thin to recognize air-water contacts.

3. Lateral Extent of Aquifer

The Tulare aquifer is laterally continuous throughout the area of review, except on the crest of Elk Hills where there is no saturated zone (Exhibit 19; Exhibit 20; Exhibit 21). The Tulare Formation is stratigraphically continuous between the area of review and the surrounding fields in which it already is an exempt aquifer.

4. Drinking Water Wells within the Area of Review

All water well drillers in California are required to submit Well Completion Reports to the DWR, which shares these data with the KCWA. Water well records within the area of review were searched using data from the KCWA, the Department of Water Resources (DWR) Water Data Library, the DWR California Statewide Groundwater Elevation Monitoring Program, the Kern County Environmental Health Services Department (KCEHSD), the USGS National Water Information System, and USGS Professional Paper 912. The summary of results from the water well survey is provided in Exhibit 26. There were no water wells records within the area of review in the KCEHSD database. However, KCEHSD only keeps records of well destructions for about five years before they are discarded. Also, the agency did not begin keeping records of water wells until the mid-1980s.

The current status of the water wells in all agency databases was verified by site reconnaissance by Quad-Knopf (Exhibit 26). Based on searches of water well databases, well records review, and site reconnaissance, there are no known drinking water wells located within the area of review. The WKWD is the primary supplier of municipal and industrial water in this area. The WKWD has no water wells within the area of review and has no rights to drill any water wells within Elk Hills proposed Tulare aquifer exemption area.

## TYPES OF CONSTITUENTS AND TOTAL DISOLVED SOLIDS (TDS) IN FORMATION WATER

Tulare groundwater was characterized based on a review of laboratory analyses and reports provided by OEHI, DOGGR Class II UIC project information, DOGGR formation water analyses for fields in and near the Elk Hills area, and literature on groundwater in the area of review.

Groundwater samples from the Tulare Formation in the Elk Hills oil field were grouped into two main areas based on data from the following wells:

- **South Flank Area**

  43WS-13B, 84WS-13B, and 284WS-13B
  82-14B and 282WS-14B
  Test wells 48-9G and the 57WS-9G
  45WS-18G and 86WS-18G
  82-2B
- **North Flank Area**

  61WS-8R

Nearly all of the Tulare groundwater analyses were collected from Tulare water source wells on the south flank of the Elk Hills oil field. All Tulare water source wells either have been abandoned or are idle. Tables summarizing the average concentrations of Tulare groundwater constituents and laboratory analyses from individual wells are included in Exhibit 27.

1. South Flank Tulare Groundwater

The initial TDS concentrations for Tulare water source wells completed above the Amnicola claystone ranged from 4,150 to 8,720 mg/l (Exhibit 27). Below the Amnicola claystone, the initial TDS concentrations range from 7,168 to 20,000 mg/l (Exhibit 27). In the lower Tulare, where TDS concentrations exceed 10,000 mg/l, groundwater in that interval is not a protected USDW by definition. TDS concentrations in Tulare groundwater generally show a trend of increasing with depth. It is likely that this results from proximity to the underlying marine San Joaquin Formation as well as other deeper, marine rocks that contain naturally saline, connate groundwater.

A summary of these constituents and their regulatory thresholds is provided in Table 1.

**Table 1**
**Constituents in Tulare Formation Water, South Flank Wells**

| Constituent | Mean Concentration or Range | MCLs and Regulatory Thresholds | Threshold Exceeded? | % of Threshold |
|---|---|---|---|---|
| Lead[1] | 0.0208 | 0.015 | Yes | 139% |
| Selenium[2] (below Amnicola) | 0.720 | 0.05 | Yes | 1440% |
| Iron | <0.1 to 37 | 0.3 | In some analyses | Up to 12,333% |
| TDS[3] (above Amnicola) | 4,150 to 8,720 | 500 | Yes | 830% to 1,744% |
| TDS[3] (below Amnicola) | 7,168 to 20,000 | 500 | Yes | 1434% to 4,000% |
| Chloride[4] | 1,625 | 250 (recommended) | Yes | 650% |
| | 1,435 | 250 (recommended) | Yes | |

| | | | | |
|---|---|---|---|---|
| Sulfates[5] | | | | 574% |
| Boron[6] | 6.16 | <0.5 - >3.0 | Yes | 205% to 1,232% |
| Strontium[7] | 5.0 to 6.8 | 4 | Yes | 125% to 170% |
| Sodium[8] | 1,217 | <3 to <69 | Yes | 1,764% to 40,567% |
| Arsenic | 0.0047 | 0.010 | No | -- |
| Copper | <0.04+ | 1.0 | No | -- |
| Molybdenum | 0.103 | None | -- | -- |
| Nickel | 0.0559 | 0.1 | No | |
| Zinc | 0.049 to 0.0589 | 5.0 | No | -- |
| | | | | |
| **NOTES:** | | | | |
| All concentrations and regulatory limits are in mg/l. | | | | |
| | Primary MCLs are shown in red. | | | |
| | Secondary MCLs are shown in orange. | | | |
| | Other regulatory thresholds are shown in yellow. | | | |

[1]The MCL for lead is 0.015 mg/l, and its maximum contaminant level goal (MCLG) is 0 mg/l. The environment screening level (ESL) for lead in groundwater is 0.0002 mg/l.

[2]Primary MCL for selenium: 0.050 mg/l

[3]Secondary MCLs for TDS: recommended = 500 mg/l; upper = 1,000 mg/l; short term = 1,500 mg/l

[4]Secondary MCLs for chloride: recommended = 250 mg/l; upper = 500 mg/l; short term = 600 mg/l. The chloride water quality guideline for sprinkler irrigation is <106 mg/l. Irrigation water for sensitive crops is recommended to be <142 mg/l.

[5]Secondary MCLs for sulfate: recommended = 250 mg/l; upper = 500 mg/l; short term = 600 mg/l.

[6]The EPA's lifetime health advisory (LHA) for boron is 6 mg/l, and its drinking water equivalent level (DWEL) for boron is 7 mg/l. Boron concentrations as low as 0.5 mg/l may be toxic to certain sensitive plants; severe usage restrictions are recommended for concentrations greater than 3.0 mg/l. The upper limit for livestock drinking water is 5.0 mg/l.

[7]The EPA's LHA level for strontium is 4 mg/l for a 70-kg adult consuming 2 liters water/day.

[8]Recommended sodium levels for surface irrigation, which are based on toxicity from root absorption, are <3 mg/l) and for sprinkler irrigation are <69 mg/l.

Tulare groundwater in the Elk Hills south flank area has: 1) a concentration of lead that exceeds the primary MCL for drinking water; 2) TDS, chloride, and sulfate concentrations in excess of secondary drinking water MCLs in every groundwater analysis; 3) boron, strontium, and sodium concentrations in excess of regulatory thresholds for human health, agricultural uses, and/or livestock watering; and 4) iron concentrations that are variable but exceed the secondary drinking water MCL in some analyses.

Some areas of the south flank have TDS concentrations in Tulare groundwater in excess of 10,000 mg/l, shown in green in the cross-sections in Exhibit 21. Tulare groundwater in these areas, typically near its base, does not meet the definition of a protected USDW and automatically qualify those zones as exempt aquifers. An example of groundwater quality in a non-protected USDW is included in Exhibit 27 for the 82-2B well. This south flank well is completed only in the lower Tulare interval. Groundwater analyses from the 82-2B well had a TDS concentration of 20,000 mg/l. It also has: a concentration of selenium which exceeds the primary MCL; chloride and sulfate concentrations in excess of recommended secondary MCLs: and concentrations of boron, strontium, and sodium greater than regulatory thresholds for protection of human health, agriculture, and/or livestock.

## 2. North Flank Tulare Groundwater

The 61WS-8R well, located in the northwestern part of the field, averaged 7,009 mg/l TDS in 1979 (Exhibit 27-1); Bechtel Petroleum Operations, Inc., 1994). When groundwater from this well was analyzed on May 17, 1988, TDS had increased to 8,720 mg/l. TDS concentrations in the 61WS-8R well exceed secondary MCLs for drinking water by 1,744%. Other analyses from 61WS-8R were: chloride 2,262 mg/l; sulfate 1,295; and boron 10 mg/l, all of which were significantly in excess of secondary MCLs and regulatory thresholds for human health, agricultural use, and livestock watering.

3. Characterization Summary for Tulare Groundwater in the Elk Hills Oil Field

Tulare groundwater constituents from two areas of the Elk Hills oil field are summarized below (Table 1; Table 2; Exhibit 27).

- One Tulare groundwater sample in the south flank of the Elk Hills oil field contained a concentration of lead that exceeds the primary MCL for drinking water.
- Every Elk Hills Tulare groundwater analyses in Exhibit 27 had TDS, chloride, and sulfate concentrations that significantly exceed secondary MCLs for drinking water.
- Iron concentrations in Tulare groundwater are variable, ranging from undetectable to significantly higher than secondary MCLs (Exhibit 27).
- All Tulare groundwater analyses of boron and sodium in Exhibit 27 exceed regulatory thresholds for human health, agricultural uses, and/or livestock watering.
- Although strontium was analyzed in only four Tulare groundwater samples, it exceeds the regulatory threshold for human health in all four analyses.

Where TDS concentrations are less 10,000 mg/l TDS, Tulare groundwater generally is of extremely poor quality and unfit for MUN (Table 1 through Table 2) and AGR purposes (Table 3). Areas of the Elk Hills oil field have Tulare groundwater with TDS concentrations in excess of 10,000 mg/l. These areas, which typically occur near the base of the Tulare, are shown in green shading on the cross-sections in Exhibit 21. These high TDS zones in the lower Tulare do not meet the definition of a protected USDW and therefore would be exempt aquifers. The Tulare Formation in the Elk Hills oil field also has producible quantities of hydrocarbons and/or oil and gas shows, particularly in the areas of sections 19R, 28R, 29R, 30R, 33R, 31S, 13Z, 14Z, and 25Z, as discussed in Section I of this document. Hydrocarbons, even if not commercial, represent an additional contaminant to be removed if Elk Hills Tulare groundwater were to be treated for use as drinking water.

**Table 2: Summary of Tulare Groundwater Constituents**

| | | Primary or | Regulatory |
|---|---|---|---|

| Constituent | Range (mg/l) | Secondary MCL (mg/l) | Threshold (mg/l)* |
| --- | --- | --- | --- |
| Lead | 0.0208 | 0.015 | 0 to 0.0025 |
| Selenium | Below Amnicola: 0.720 | 0.050 | |
| Iron | <0.1 to 37 | 0.3 | |
| TDS | 4,150 to 8,720<br>Below Amnicola: 7,168 to 20,000 | 500 (recommended) | >2,000 |
| Chloride | 1,000 to 6,049.5 | 250 (recommended) | >3 to >10 |
| Sulfate | 340 to 1,800 | 250 (recommended) | |
| Boron | 3.7 to 10.0 | -- | 0.0016 to 7 |
| Sodium | 856 to 1,800 | -- | <3 to <69 |
| Strontium | 5.0 to 6.8 | | 4.0 |
| Hydrocarbons | Variable | -- | -- |

**Table 3: Guidelines for interpretations of Water Quality for Irrigation**

| Potential Irrigation Problem | Units | Degree of Restriction on Use | | |
|---|---|---|---|---|
| | | None | Slight to Moderate | Severe |
| **Salinity** *(affects crop water availability)*[2] | | | | |
| $EC_w$ | dS/m | < 0.7 | 0.7 – 3.0 | > 3.0 |
| **TDS** | **mg/l** | **< 450** | **450 – 2000** | **> 2000** |
| **Specific Ion Toxicity** *(affects sensitive crops)* | | | | |
| Sodium (Na)[4] | | | | |
| sprinkler irrigation | me/l | < 3 | > 3 | |
| Chloride (Cl)[3] | | | | |
| surface irrigation | me/l | < 4 | 4 – 10 | > 10 |
| sprinkler irrigation | me/l | < 3 | > 3 | |
| **Boron (B)[4]** | **mg/l** | **< 0.7** | **0.7 – 3.0** | **> 3.0** |
| Trace Elements (see Table 21) | | | | |
| **Miscellaneous Effects** *(affects susceptible crops)* | | | | |
| Nitrogen ($NO_3$ – N)[5] | mg/l | < 5 | 5 – 30 | > 30 |
| Bicarbonate ($HCO_3$) | | | | |
| *(overhead sprinkling only)* | me/l | < 1.5 | 1.5 – 8.5 | > 8.5 |
| pH | | Normal Range 6.5 – 8.4 | | |

1 Adapted from University of California Committee of Consultants, 1974 (See Ayers & Westcot, 1994).

2 Ecw means electrical conductivity, a measure of the water salinity, reported in deciSiemens per meter at 25°C (dS/m) or in units millimhos per centimeter (mmho/cm). Both are equivalent. TDS is reported in mg/l.

3 For surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride; use the values shown. Most annual crops are not sensitive; use the salinity tolerance tables (Ayers & Westcot Tables 4 and 5). For chloride tolerance of selected fruit crops, see Ayers & Westcot, 1994, Ayers & Westcot Table 14. With overhead sprinkler irrigation and low humidity (< 30 percent), sodium and chloride may be absorbed through the leaves of sensitive crops. For crop sensitivity to absorption, see Ayers & Westcot, 1994, Ayers & Westcot Tables 18, 19 and 20.

4 For boron tolerances, see Ayers & Westcot, 1994, Ayers & Westcot Tables 16 and 17.

5 $NO_3$ –N means nitrate nitrogen reported in terms of elemental nitrogen ($NH_4$ –N and Organic-N should be included when wastewater is being tested).

In the area surrounding the Elk Hills oil field, TDS concentrations in Tulare groundwater also are naturally high (Exhibit 29). Regional studies of groundwater in the western San Joaquin Valley confirm that high concentrations of salts in Tulare groundwater are the result of: 1) naturally saline, connate waters; 2) migration of brines from deeper zones by the same processes that caused local petroleum occurrences; 3) agency-permitted surface and subsurface disposal of briny produced water; and 4) enclosed groundwater basin geometry (Western Oil and Gas Association, 1983; Bean & Logan, 1983; Weddle, 1968).

## 4. Salinity Calculations

Calculations of salinity in the Elk Hills oil field follow guidelines published by the US EPA (Davis, 1988). The Humble equation was selected because its critical parameters, including deep resistivity and density porosity, are available for the calculations. Also known as the RP Method, the Humble equation is the most widely-used formula for unconsolidated sands (Davis, 1988) that are typical of the Tulare Formation. Discussion of the method used for salinity calculations is included in Exhibit 30.

Direct samples of water salinity are available only from a small group of wells at Elk Hills. In general, these wells are former Tulare water source wells. Water quality was sampled in order to analyze compatibility of Tulare groundwater with Miocene Stevens zone waterfloods. Most of these wells do not have full geophysical log suites. However, more recent nearby development wells or water disposal wells do have complete log suites. Therefore, it is possible to compare sampled water salinity to calculated salinity. A limitation of this analysis is that the former Tulare water source wells were completed over a very long interval. As a result, multiple intervals of varying calculated salinities are present within the borehole and contribute to the groundwater sampled.

Well 48-9G has some of the best water salinity information at Elk Hills. Two intervals in the lower Tulare were tested: an upper interval from 595 to 935 feet, and a lower interval from 1,040 to 1,275 feet (Exhibit 30). Two water samples from the upper interval had salinities of 7,453 and 7,168 mg/l TDS. Three samples from the lower interval, taken over a week-long period, changed from 12,647 to 9,926 ppm TDS. The change in salinity may be caused by increased flow from more permeable sands having lower salinity. Three nearby wells, located within 600 feet of 48-9G, were selected for calculation of salinity. The three wells record a progressive increase in salinity, from shallow to deep, generally ranging from about 6,000 mg/l TDS at about a measured depth of 600 feet to greater than 13,000 mg/l TDS near the base of the Tulare. For both the upper and lower tested intervals, all sampled formation water salinity measurements fell within the range of calculated salinity values in stratigraphically equivalent intervals, and the principle that salinity increases with depth in the Tulare Formation is well-established in this example.

Three Tulare water source wells have measurements of formation water salinity and also have nearby wells with modern geophysical suites that permit the calculation of salinity using the Humble equation. Wells 45WS-18G and 86W-18G were completed over an interval of more than 1,000 feet and have measured salinities of 4,700 to 5,800 mg/l TDS (Exhibit 30). Nearby wells, which are located within 1,700 feet, have calculated salinity values that bracket the measured values. Likewise, well 284WS-13B had an initial salinity test of 5,744 mg/l TDS initially but declined to 4,500 mg/l after a year (Exhibit 30). Calculated salinity in nearby well 54WD-13B, located 1,580 feet west, ranges from 4,000 mg/l TDS in the shallow interval to 5,000 mg/l in the deep. The occurrence of initially higher salinity in tests is attributed to contributions of formation water from below the calculated zones in the nearby well. Over time, shallower and more permeable zones began to dominate production in the water source well. Just as in the structurally higher parts of Elk Hills, salinity increases with depth in the flank areas as well.

Elk Hills calculated salinity data compare closely to actual measured groundwater samples, or, more frequently, calculated values are less than actual groundwater sample values, with the error amount up to 30%. In no case do calculated values exceed actual groundwater samples values by more than 1%. The error may be caused by the large amount of open interval and that deeper, higher salinity formation water makes up a significant portion of the sample. In wells with more restricted sample intervals, such as 48-9G and 82-2B, errors ranged from 6 to 21%. This amount of error is consistent with that noted by Davis (1988). Based on this comparison, calculated salinity is equal to or less than values from actual tested groundwater samples. Calculated salinity values of groundwater-bearing intervals of the Tulare Formation show a trend of increasing salinity with depth. Salinity in the upper Tulare on the flanks of Elk Hills has values between 3,500 and 6,000 mg/l TDS. Calculated salinities in sand intervals below the Amnicola claystone range from 6,000 to 24,000 mg/l TDS. Salinity in at least the lowermost 240 feet of the basal Tulare is greater than 10,000 mg/l TDS. This calculation of high salinity is confirmed by formation water tests in well 48-9G. Comparison of calculations using the RP method, or Humble equation, and formation water tests shows that calculated salinity is equal to or less than the actual groundwater analyses, but the underestimation error is no more than 21%.

## YIELD OF GROUNDWATER

1. Permeability

Conventional core analyses from wells in the Elk Hills oil field were used to determine permeability in the Tulare Formation. Based on Tulare sand and sandstone units in the Bechtel UONPR #1 CH-27R and the Williams Brothers 36-30R, the average vertical and horizontal permeabilities are 1,314 millidarcies (md) and 2,723 md, respectively (Exhibit 31-1). The range of permeability is quite large because of the poor sorting of the non-marine Tulare sediments. The permeability of these units is believed to be representative of Tulare injection zones.

In the clay, silt, and siltstone units of the Tulare Formation, the vertical permeabilities range from <0.1 to 1.0 md and averages 0.7 md (Exhibit 31-2). The low vertical permeabilities of the fine-grained Tulare units demonstrate that these zones would act as effective barriers to upward migration of fluids.

Permeabilities in the area of section 30R, where the Tulare produced oil, were analyzed by Bergeson (1988). The whole curve average of 159 conventional core and sidewall samples was 434 md (Exhibit 31-3). In a 15-foot interval of “good” Tulare oil sand, the average permeability was 374 md.

2. Porosity

The porosity of the Tulare Formation was based on analyses of conventional core analyses from two wells in the Elk Hills oil field. The average porosity of the Tulare sand and sandstone units, which is considered to be representative of Tulare injection zones, is 35.8% and ranges from 12.3% to 44.2% (Exhibit 31-1). The clay, silt, and siltstone units of the Tulare Formation have an average porosity of 30.7% and ranges from 24.9% to 38.6% (Exhibit 31-2).

Porosity also was analyzed in the area of section 30R, where the Tulare produced oil (Bergeson, 1988). Based on 159 conventional core and sidewall samples, the whole curve average was 38.0% and 38.7% in a 15-foot interval of "good" Tulare oil sand (Exhibit 31-3).

3. Sand Identification

Sand can be readily identified on logs as those intervals having spontaneous potential deflections to the left and resistivity deflections to the right (Exhibit 18; Exhibit 21).

4. Fluid Levels

Initial static fluid levels from wells on the south flank of Elk Hills ranged from 247 feet to 323 feet (Table 4).

**Table 4: Initial Static Fluid Level in South Flank Area Wells**

| Well No. | Elevation (feet MSL) | Year |
|---|---|---|
| 84WS-13B | 252 | 1979 |
| 284WS-13B | 255 | 1990 |
| 43WS-13B | 284 | 1992 |
| 82WS-14B | 323 | 1980 |
| 282WS-14B | 289 | 1990 |
| 48-9G | 273 | 1978 |
| 57WS-9G | 305 | 1979 |
| 86WS-18G | 247 | 1982 |
| 45WS-18G | 250 | 1991 |

**Distance to Existing Towns**

The Tulare aquifer exemption area is located on the southwestern side of the San Joaquin Valley in a remote, unincorporated part of Kern County. The five nearest surrounding towns are:

- Buttonwillow: 5 miles to the north
- Tupman: 0.5 miles to the northeast
- Dustin Acres: 0.5 miles to the south
- Derby Acres: 3.5 miles to the southwest
- McKittrick: 2.5 miles to the west

Other towns within the area of review are shown in Exhibit 1.

**ECONOMIC EVALUATION OF TREATING MCKITTRICK AREA GROUNDWATER FOR DRINKING WATER**

On behalf of LPGC, Kennedy/Jenks Consultants prepared a technical and economic feasibility evaluation of treating Tulare groundwater in the McKittrick area for use as drinking water. The LPGC is located in the Asphalto field, which is adjacent to the Elk Hills oil field. The purpose of the report titled, "Evaluation of Economic Feasibility of Treating McKittrick Area Groundwater for Use as Drinking Water," and dated March 2002, was to evaluate whether McKittrick area groundwater could be designated as Class III water, defined as groundwater not a source of drinking water. Groundwater can be designated as Class III water if there is:

"Contamination, either by natural processes or by human activity (unrelated to a specific pollution incident), that cannot be cleaned up using treatment methods reasonably employed in public water-supply systems."

The Class III designation is based on a socioeconomic evaluation of the benefits and costs of groundwater protection. The economic infeasibility of treating groundwater for drinking water is assessed by a comparison of the cost to treat McKittrick groundwater to the current potable water treatment cost in the area. In the Kennedy/Jenks evaluation, groundwater would be classified as Class III if the cost of developing, treating, and delivering the water is: 1) more than 0.4% of the median annual income per household in the area, 2) exceeds 100% of the current annual water treatment rate, or 3) exceeds the ninetieth percentile economic untreatability threshold. The economic feasibility study had the following findings (Exhibit 40):

- A sample of McKittrick area groundwater had high concentrations of TDS (6,100 mg/l), boron (21 mg/l), sulfate (1,200 mg/l), chloride (1,600 mg/l), and hardness (1,100 mg/l).

- Tulare groundwater in the McKittrick area cannot be treated by treatment technologies by methods employed in public water systems or methods known to be used in a limited number of cases.

- Using reverse osmosis (RO) technology, McKittrick area Tulare groundwater treatment was estimated to cost $34,500 per acre-foot for a system with a design flow rate of 165,000 gallons per day (GPD) and $5,800 per acre-foot for a system with a rate of 2.85 million gallons per day (MGPD). Potable water treatment in the McKittrick area is $500 per acre-foot. The small and large RO treatment systems would be about 70 and 10 times, respectively, more than the current potable water source.

- For the 165,000 GPD and 2.85 MGPD systems, the cost to treat McKittrick area groundwater was about 75% and 13%, respectively, of the annual McKittrick area household income. These costs exceeded the US EPA's Class III guideline that the per-household share of treatment cost should not be more than 0.4% of the area per-household income.
- A second US EPA economic threshold is that increase in annual water cost per household should not exceed 100%. In the Kennedy/Jenks study, the annual water cost per average household in the McKittrick area was $255. The increase in annual water cost per household to treat Tulare groundwater in the McKittrick area was $17,345, or about 6,800% increase, for the 165,000 GPD system and $2,695, or a 1,060% increase, for the 2.85 MGPD system. Because costs for both systems are significantly greater than the US EPA's economic criteria of no more than a 100% increase, the economic criteria for the Tulare groundwater in the McKittrick area being classified as Class III groundwater, or groundwater not a source of drinking water, was met.
- Because the two US EPA criteria for economic infeasibility were met, it was concluded that McKittrick area groundwater should be designated as Class III, or groundwater not a source of drinking water.

The June 1998 US EPA guidelines for classifying groundwater also have an economic untreatability threshold based on the annualized total costs of replacement or hypothetical systems that exceed the costs faced by 90% of community water-supply system users (U.S. Environmental Protection Agency, 1988). This ninetieth percentile economic untreatability threshold is calculated using the following equation:

*Threshold = [(-200.255) x Log (Size)] + 1,248.727*
*Where:*
*Threshold = Threshold cost in dollars per household per year*
*Size = User population, in individuals*

For a McKittrick area population size of 22,000:
*Threshold = [(-200.255) x Log (22,000)] + 1,248.727*
*= $379.14*

The Kennedy/Jenks study calculated increases in costs of $17,345 per household for the 165,000 GPD small system and $2,695 per household for the 2.85 MGPD large system are significantly in excess of the ninetieth percentile economic untreatability threshold of $379.14 per-household by a factor of about 46 and 7 times, respectively. Because this US EPA economic untreatability guideline also was met, McKittrick area groundwater was demonstrated to be classified as Class III, or groundwater not a source of drinking water.

Mr. Fernando Granizo, an OEHI facilities engineer, reviewed the Kennedy/Jenks study to determine if water treatment costs would still be relevant. SJEC provided updated information on median household income, number of persons per household, per capita water usage, and households/population served. OEHI concluded that the economics of the earlier study were relatively comparable and that the cost to treat Tulare groundwater in the Elk Hills oil field for use as drinking water would still be economically infeasible.

Tulare groundwater in the Elk Hills oil field contains high concentrations of TDS, iron, chloride, sulfate, boron, and sodium, which are comparable to the McKittrick area groundwater in the Kennedy/Jenks report (Table 9). However, it also locally contains hydrocarbons and strontium, as well as a high concentration of lead, all of which would need to be treated before being used as drinking water. These additional sources of contamination in Elk Hills Tulare groundwater would increase treatment costs and, consequently, increase the economic infeasibility to treat it for use as drinking water. For this reason, the Tulare groundwater in the Elk Hills oil field should be considered as Class III groundwater. It is believed that the Tulare groundwater has a low resource value except for use in Class I non-hazardous and Class II UIC injection operations.

**Table 9**
**Comparison of Tulare Groundwater in the Elk Hills Field and the McKittrick Area**

| Constituent | Tulare Groundwater McKittrick Area (mg/l)* | Tulare Groundwater Elk Hills Field (mg/l) |
|---|---|---|
| Lead | <0.05 | 0.0208 |
| Selenium | <0.05 | Below Amnicola claystone: 0.720 |
| Iron | 0.56 | <0.1 to 37 |
| TDS | 6,100 | 4,150 to 8,720<br>Below Amnicola: 7,168 to 20,000 |
| Chloride | 1,600 | 1,000 to 6,049.5 |
| Sulfate | 1,200 | 840 to 1,800 |
| Boron | 21 | 3.7 to 10.0 |
| Sodium | 1,300 | 856 to 1,800 |
| Strontium | Not analyzed | 5.0 to 6.8 |
| Hydrocarbons | Not analyzed | Variable |

## Conclusion

The regulatory criteria to approve an aquifer exemption that must be met are included in 40 CFR, Section 146.4. State of California, both the Division of Oil, Gas, and Geothermal Resources (Primacy Administrator) and the State Water Resources Control Board, agree and put forward this aquifer exemption application based on the following:

The aquifer is not currently used as a drinking water source and:

1. It is situated at a depth or location which makes the recovery of water for drinking water purposes economically or technologically impractical, and
2. The water is so contaminated that it would be economically or technologically impractical to render the water fit for human consumption, and
3. The TDS is more than 3,000 and less than 10,000 mg/l and it is not reasonably expected to supply a public water system.

Although the Executive Summary includes most of the supporting data, if you require addition supporting documentation, please refer to the attached document prepared by San Joaquin Energy Consultants, Inc. for Occidental of Elk Hills, Inc.

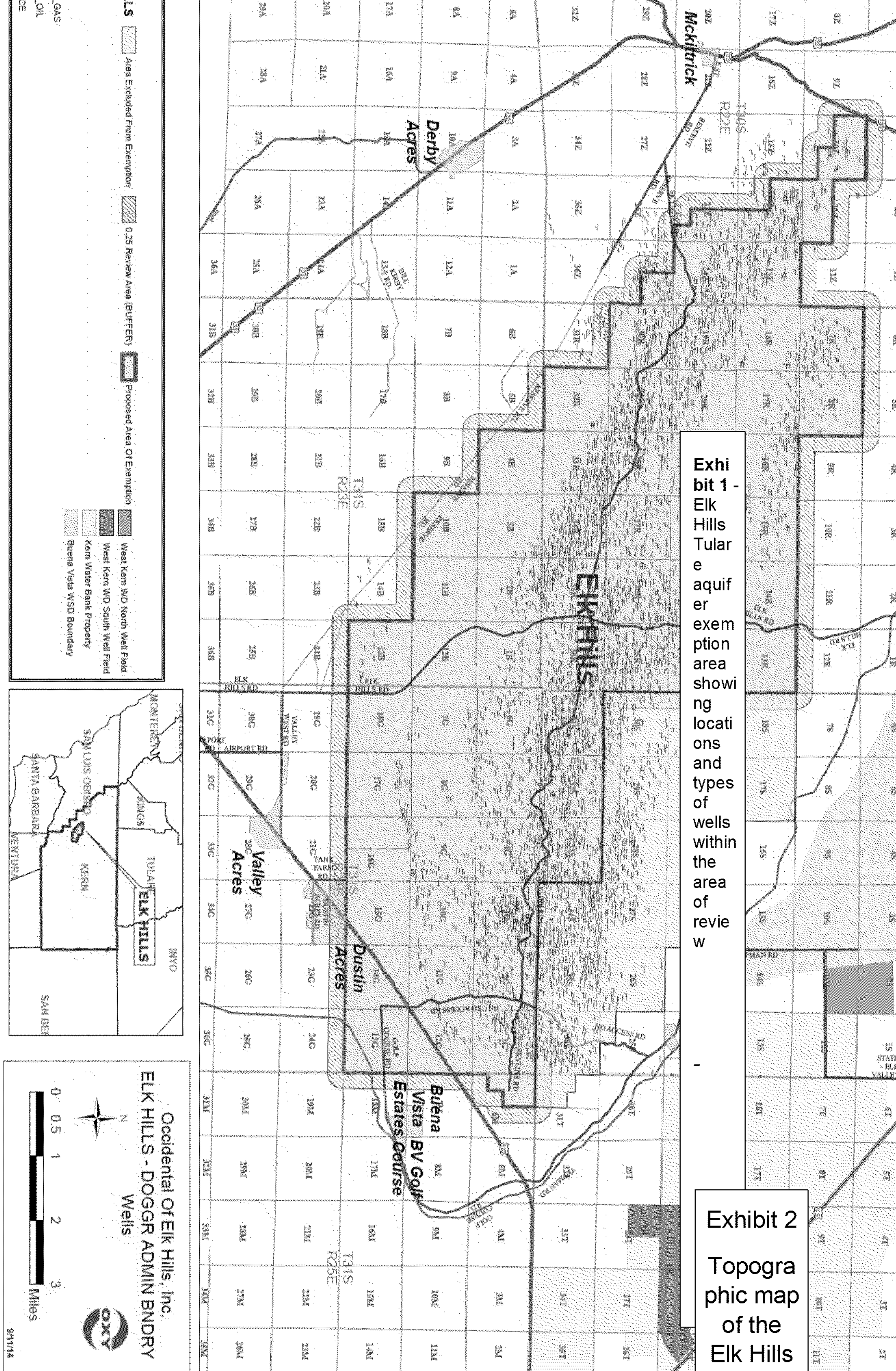


**Exhibit 1** - Elk Hills Tulare aquifer exemption area showing locations and types of wells within the area of review

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Exhibit 2

Topographic map of the Elk Hills field showing existing Tulare aquifer exemptions in all or portions of the surrounding oil

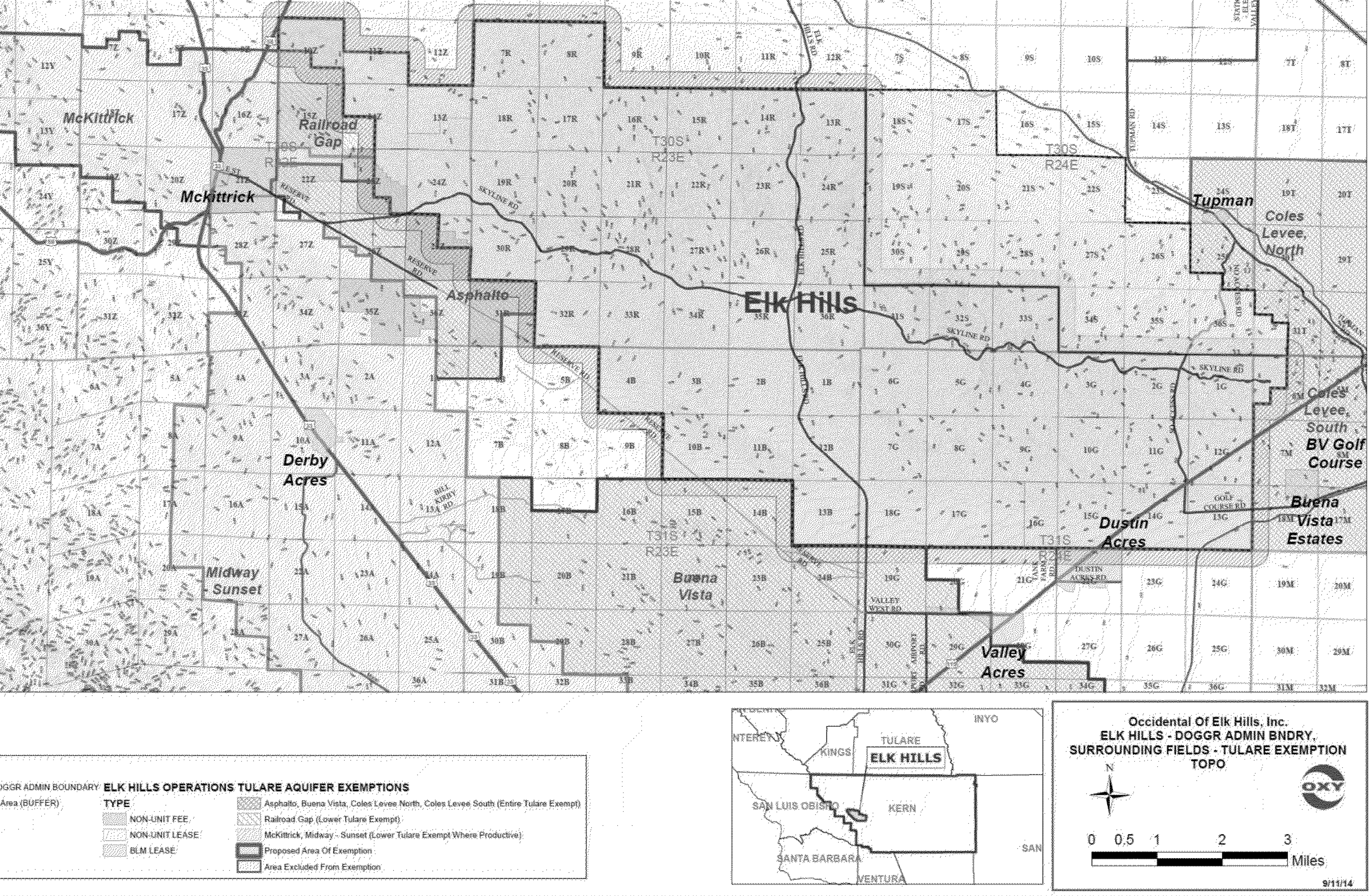
McKittrick
Mckittrick
Railroad Gap
T30S R22E
T30S R23E
T30S R24E
T31S R23E
T31S R24E
Asphalto
Elk Hills
Tupman
Coles Levee, North
Coles Levee, South
BV Golf Course
Buena Vista Estates
Dustin Acres
Derby Acres
Midway Sunset
Buena Vista
Valley Acres
SKYLINE RD
RESERVE RD
TUPMAN RD
ELK HILLS RD
GOLF COURSE RD
DUSTIN ACRES RD
VALLEY WEST RD
BILL KIRBY RD
TULARE
KINGS
ELK HILLS
INYO
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
DOGGR ADMIN BOUNDARY
Area (BUFFER)
ELK HILLS OPERATIONS TULARE AQUIFER EXEMPTIONS
TYPE
NON-UNIT FEE
NON-UNIT LEASE
BLM LEASE
Asphalto, Buena Vista, Coles Levee North, Coles Levee South (Entire Tulare Exempt)
Railroad Gap (Lower Tulare Exempt)
McKittrick, Midway - Sunset (Lower Tulare Exempt Where Productive)
Proposed Area Of Exemption
Area Excluded From Exemption
Occidental Of Elk Hills, Inc.
ELK HILLS - DOGGR ADMIN BNDRY,
SURROUNDING FIELDS - TULARE EXEMPTION
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**Exhibit 3**
**Declaration from the Local Water Agency**

water district



September 19, 2014

Mr. Bill Penderel
Associate Oil & Gas Engineer
Division of Oil, Gas, and Geothermal Resources
UIC Program
Via Email

**RE: OCCIDENTAL ELK HILL, INC. TULARE AQUIFER EXEMPTION DOCUMENT ELK HILLS FIELD**

Dear Mr. Penderel,

On May 15, 2014 San Joaquin Energy Consultants (SJEC) on behalf of Occidental of Elk Hills, Inc., (OEHI) contacted West Kern Water District (WKWD), stating they were in the process of preparing an application in the Elk Hills oilfield for an aquifer exemption for the Tulare Formation in portions of the Elk Hills project to allow Class II UIC Injection Operations, within the WKWD service area,.

SJEC requested WKWD provide the Division of Oil, Gas and Geothermal Resources a letter stating the Tulare aquifer does not currently serve as a source of drinking water, and it would not reasonably be expected to supply a public water system within the project area as shown in the application map Exhibit 1-1 (and attached).

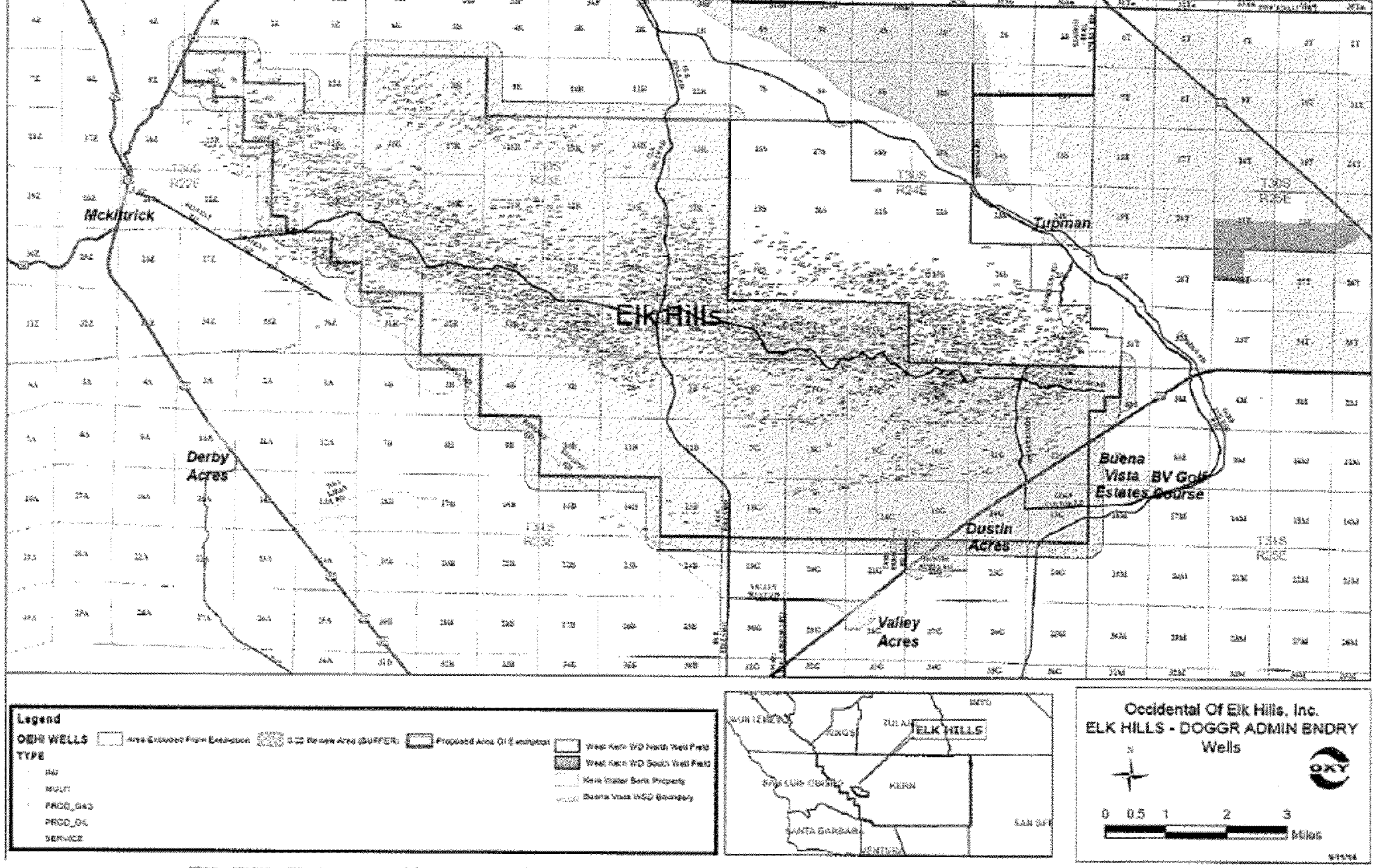
WKWD Staff and the District's consulting hydrogeologist have reviewed water quality data and various reports provided by SJEC within the project area and concluded the Tulare aquifer does not currently serve as a source of drinking water, and it would not reasonably be expected to supply a public water system in the project area shown on the application map.

On September 15, 2014 the West Kern Water District - Board of Directors authorize Staff to issue a letter to the Division of Oil, Gas and Geothermal Resources stating the Tulare aquifer does not currently serve as a source of drinking water, and it would not reasonably be expected to supply a public water system in the project area as shown on the application map Exhibit 1-1.

Should you require further correspondence regarding this subject please contact JD Bramlet of my Staff at (661) 763-3151.

Sincerely,

Harry O. Starkey
General Manager



Elk Hills Tulare aquifer exemption area showing locations and types of wells within the area of review